RDT&E PROJECT JUSTIFICATION SHEET (R-2)	February 2004
OPERATIONAL TEST AND EVALUATION, DEFENSE (0460) BUDGET ACTIVITY THREE	TEST AND EVALUATION/SCIENCE AND TECHNOLOGY (T&E/S&T) PROGRAM ELEMENT (PE) 0603941D8Z

$'s in Millions	FY 2003	FY 2004	FY 2005	FY 2006	FY 2007	FY 2008	FY 2009
PE 0603941D	8.571	12.804	16.295	28.871	43.318	65.301	97.669
Hypersonic Test	2.305	2.211	3.168	6.053	10.467	16.028	26.812
Spectrum Efficient Technology	2.199	2.149	2.417	3.953	4.339	5.415	6.329
Multi-Spectral Test	1.498	2.079	2.620	3.171	5.190	8.248	12.728
Embedded Instrumentation	1.417	3.309	2.663	3.982	4.983	7.949	11.743
Directed Energy Test	1.152	3.006	4.327	5.887	9.763	14.967	24.808
Information Systems Technology Test	0.000	0.050	1.100	1.968	2.247	3.447	4.077
Software Test	0.000	0.000	0.000	1.857	2.338	3.380	4.156
Modeling and Simulation	0.000	0.000	0.000	1.000	1.922	2.967	3.480
Test Range/Facility Technology Improvements	0.000	0.000	0.000	1.000	2.069	2.900	3.536

A. (U) MISSION DESCRIPTION AND BUDGET ITEM JUSTIFICATION

The T&E/S&T program seeks out and develops test technologies to pace evolving weapons technology. This program is critical to ensuring the DoD has the capability to adequately test the advanced systems that will be fielded in the future. To meet this objective, the T&E/S&T program:

- Exploits new technologies and processes to meet important T&E requirements
- Expedites the transition of new technologies from the laboratory environment to the T&E community
- Leverages commercial equipment and networking innovations to support T&E

Additionally, the program examines emerging test requirements derived from transformation initiatives to identify needed technology areas and develop a long-range roadmap for technology insertion. This program leverages and employs applicable 6.2 applied research from the highly developed technology base in the DoD Laboratories and Test Centers, industry, and academia to accelerate the development of new test capabilities.

Official Travel:

Perform official travel to carry out oversight of the T&E/S&T program.

This Research Category 6.3, Advanced Technology Development PE, develops and demonstrates high payoff technologies for current and future DoD test capabilities.

B. (U) PROGRAM CHANGE SUMMARY

($ in Millions)	FY 2003	FY 2004	FY 2005
FY 2004 President's Budget	8.571	12.804	19.413
Current Budget Submit	8.571	12.804	16.295
Total Adjustments			(3.118)
Congressional Program Reductions			
Congressional Rescissions			
Congressional Increases			
Program Adjustment			(3.000)
Inflation Adjustment			(0.118)

C. (U) OTHER PROGRAM FUNDING NA

RDT&E PROJECT JUSTIFICATION SHEET (R-2a)			February 2004				
OPERATIONAL TEST AND EVALUATION, DEFENSE (0460) BUDGET ACTIVITY THREE, PE 0603941D			HYPERSONIC TEST				
$'s in Millions	FY 2003	FY 2004	FY 2005	FY 2006	FY 2007	FY 2008	FY 2009
Hypersonic Test	2.305	2.211	3.168	6.053	10.467	16.028	26.812

A. (U) MISSION DESCRIPTION AND BUDGET ITEM JUSTIFICATION

The National Aerospace Initiative (NAI) will develop air-breathing weapons, advanced aircraft, and access to space platforms to operate in the hypersonic speed regimes Mach 5 and higher. Hypersonic systems to be developed under the NAI require T&E capabilities in numerous areas ranging from ground testing (wind tunnels, sled tracks, installed-system test facilities, and modeling and simulation (including computational fluid dynamics)), through flight testing (entailing large geographical areas and huge safety footprints) that exceed current test capabilities. At hypersonic speeds, flight testing will also challenge existing ground instrumentation systems (e.g., tracking system slew rate limitations, ionization dropouts) and range safety decision making. Near-term hypersonic applications are focused on developing technologies for munitions and weapons for time critical and mobile targets, advanced global reach aircraft, and access to space platforms that will operate in the hypersonic speed regimes; i.e., Mach 5 to Mach 16. Hypersonic weapon systems will depend on several new technological thrusts in areas such as propulsion and engines, structures and materials, guidance and control, seekers and sensors, warheads and payloads, and weapons delivery techniques and end-game dynamics, each requiring supporting T&E capabilities to determine performance, effectiveness, suitability, survivability, and responsiveness to Command, Control, Communications, Computers, Intelligence, Surveillance and Reconnaissance (C4ISR) systems. Service improvement and modernization programs are addressing some basic test facility upgrades using off-the-shelf technologies. However, T&E of hypersonic systems will require technologies not yet developed or available for T&E purposes. The NAI and DoD must have adequate T&E capabilities in place in time to meet current development and acquisition program schedules. The purpose of this T&E/S&T focus area is to address these T&E technology issues.

B. (U) ACCOMPLISHMENTS/PLANNED PROGRAM

	FY 2003	FY 2004	FY 2005
Hypersonic Test	2.305	2.211	3.168

FY 2003 Accomplishments:

Investigations initiated in Hypersonic Test in FY 2002 continued throughout FY 2003. The Hypersonic Wind Tunnel Nozzle Survivability for T&E effort characterized and evaluated alloys and coatings that show promise for high-temperature survivable nozzles required for hypersonic testing, and examined nozzle cooling techniques. The In-Situ Pressure Measurements for Hypersonic Vehicles designed and began fabrication of a proof-of-concept Microelectromechanical Systems (MEMS) pressure sensor on a silicon-carbide chip to allow for measurement of pressures within hypersonic systems.

The Heat Flux Sensor Development for Hypersonic Aerothermal Measurement project fabricated prototype sensors and performed target of opportunity tests that included tests to support the Space Shuttle return to flight efforts. The Advanced Flight Vehicle Instrumentation effort conducted a series of proof-of-concept experiments that demonstrated optical sensor performance for combustor testing. These new sensors detected an unknown combustor ignition phenomenon that will be analyzed as part of the NAI.

Progress continued on the Hypersonic Aeropropulsion System Flight Trajectory T&E, which is developing a capability to emulate a hypersonic "fly-the-mission" profile by varying the Mach number in the wind tunnel. T&E requirements for time-dependent Mach variation were assessed, and a technique was selected to achieve acceleration flight trajectory testing. The project also developed the isobutane burner technology needed to provide the required Mach number variation capabilities. This burner technology is being considered to improve flight condition simulation at Arnold Engineering Development Center.

Two new efforts were initiated: Onboard Data Acquisition for Hypersonic Combustion Research, which will develop a survivable data acquisition system with soft-recovery capability for hypersonic flight tests, and the Hypersonic Clean Air Heater Test Technology, which will develop ceramic resistance-type heater technology to provide clean air for hypersonic testing to Mach 7.

FY 2004 Plans:

Investigations initiated in FY 2002 and FY 2003 will continue. Specific developments and demonstrations planned for these projects are:

- Hypersonic Wind Tunnel Nozzle Survivability for T&E will fabricate nozzle throats using newly developed alloys and evaluate these throats in an existing ultra-high pressure blow-down facility (Magnetohydrodynamics Accelerator Research into Advanced Hypersonics (MARIAH) concept facility). The initial demonstration will occur this year followed by the planned transition to multiple facilities.
- In-Situ Pressure Measurements for Hypersonic Vehicles will fabricate MEMS pressure sensing devices with on-chip amplification and temperature compensation and then conduct tests with these sensors to observe their performance. The testing using combustor materials from a hypersonic vehicle will complete in FY 2004.

- Heat Flux Sensor Development for Aerothermal Measurements will generate calibrated heat flux sensors and test these sensors at high heat flux levels. Efforts will also develop microminiature assemblies to support wind tunnel testing. Testing and refinement of prototype sensors will continue through this year.
- Advanced Flight Vehicle Instrumentation will complete reporting on optical sensor integration and designs for distributed onboard optical data systems. These designs will be transitioned to the DARPA HyFly program.
- Hypersonic Aeropropulsion System Flight Trajectory T&E will continue to develop technology required for a variable Mach number generation system. This effort is developing a method to alter the geometry of supersonic freejet nozzles by rotating the air heater with respect to the article under test.
- Hypersonic Clean Air Heater Test Technology will complete design studies, pilot heater development, and materials property testing initiated in FY 2003.
- Onboard Data Acquisition for Hypersonic Combustion Research will conduct proof-of-principle tests, ballistic vehicle nose tests, and flow-through model tests to demonstrate the ability of an onboard data acquisition system to survive under hypersonic conditions.

The Hypersonic Wind Tunnel Nozzle Survivability for T&E, In-Situ Pressure Measurements for Hypersonic Vehicles and Advanced Flight Vehicle Instrumentation projects are all scheduled for completion in FY 2004. New efforts on high-speed sled mounted nozzles and advanced heater development concepts will be initiated. An investigation to improve predictions of flight vehicle propulsion performance based on vitiated air (air contaminated by heating) data from ground test facilities will also be initiated. A Broad Agency Announcement will be issued to identify candidate efforts for FY 2005.

FY 2005 and Future Plans:

Projects identified by the FY 2004 Broad Agency Announcement process will be initiated. Future investigations will be launched to address T&E technology challenges in this focus area including:

- Flight testing:
  - Providing continuous and survivable (at least through the test mission) telemetry, time-space position and attitude information, and command/control (including flight termination systems) through target engagement
  - Providing data for evaluation of performance, effectiveness, suitability, survivability, and recovery
  - Providing inter-range operations, ground instrumentation (tracking, data stream reception), and range safety and non-destructive flight termination capabilities
  - Weapons separation and end-game dynamics
  - High velocity flight control

- Ground testing:
  - Realistic ground test environments (wind tunnel, computational fluid dynamics (CFD), magnetohydrodynamics, installed-system test facility, sled track, propulsion test stands) and capabilities to adequately simulate flight conditions with associated targets and countermeasures conditions
  - Onboard survivable sensors and instrumentation systems
  - Aerodynamic aerothermal heating and cooling
  - Structures and materials effects.

C. (U) OTHER PROGRAM FUNDING NA

RDT&E PROJECT JUSTIFICATION SHEET (R-2a)	February 2004
OPERATIONAL TEST AND EVALUATION, DEFENSE (0460) BUDGET ACTIVITY THREE, PE 0603941D	SPECTRUM EFFICIENT TECHNOLOGY

$'s in Millions	FY 2003	FY 2004	FY 2005	FY 2006	FY 2007	FY 2008	FY 2009
Spectrum Efficient Technology	2.199	2.149	2.417	3.953	4.339	5.415	6.329

A. (U) MISSION DESCRIPTION AND BUDGET ITEM JUSTIFICATION

Increasing commercial use of the radio frequency (RF) spectrum and DoD's higher demands for bandwidth and test data are impacting the capability to test current weapon systems. Realistic testing of modern military systems, and follow-on training at the completion of a defense system's development phase, rely heavily on the use of the RF spectrum, especially in the "L" and "S" microwave bands. Signal propagation, supportable data rates, and other related characteristics make these bands ideally suited for test telemetry and training applications. However, these are the same characteristics that make these bands highly coveted by the wireless communications industry. The growth in the demand for consumer communication services has resulted in an increasing reallocation of RF spectrum from government to non-government use. The reallocation of this spectrum, coupled with the increase in activities that use it, has raised concerns regarding the availability of adequate spectrum to support test and training. Current and future major flight test programs such as the F-22, Joint Strike Fighter, Future Combat Systems, Airborne Laser, and the Ballistic Missile Defense System (BMDS) will experience increased competition for spectrum. Compromises will be required, and some programs may have to reduce the number of tests and/or modify schedules unless technological advances are achieved in the spectrum efficiency focus area. New technology development is required to increase the efficiency of the remaining spectrum allocations, and to begin investigations into possible use of unused or lesser-used parts of the spectrum.

Each new generation of military systems typically generates ten times more data and information than the system it is replacing, resulting in a 20-year trend of exceptional growth in the demand for test and training related spectrum. The next generation of systems will generate proportionately greater data rates that will exceed the capability of our current test infrastructure. This T&E/S&T focus area will develop and adapt S&T from a wide range of sources to facilitate continued test and training operations in the remaining or less-used portions of the RF spectrum, and at higher data rates.

B. (U) ACCOMPLISHMENTS/PLANNED PROGRAM

	FY 2003	FY 2004	FY 2005
Spectrum Efficient Technology	2.199	2.149	2.417

FY 2003 Accomplishments:

Two FY 2002 investigation efforts, the M-ary Variable Shift Keying and Variable Phase Shift Keying/Feher Variant High Efficiency Modulations, were completed in FY 2003. These investigations analyzed several proposed high efficiency modulation schemes to improve range communications which led to a follow-on analysis of a new modulation scheme that has potential to increase communications efficiency by a factor of three.

The Ground Antenna Study investigated ground-based receiving telemetry antennas and identified a series of feasible modifications to allow operation of existing assets in the Super High Frequency (SHF) bands and potentially allow operation simultaneously with other telemetry bands. The Spectrally Efficient High Data Rate Telemetry System for SHF simulation efforts demonstrated the ability to combine Advanced Orthogonal Frequency Division Multiplexing (AOFDM) techniques with Turbo Cross-Channel Coding (TCCC) to achieve high data rates and overcome Doppler and multipath issues. The AOFDM prototype fabrication was initiated this year to validate the predictions.

Phase I of the Steerable Beam, Directional Antenna Concepts was completed to minimize effects of communication nulls in the SHF bands. The Phase II prototype and demonstration effort began this year. The Space-Time Coding effort continued investigation into various channel estimation techniques to reduce the loss of data from signal fading. The project completed development of a breadboard encoder device that will be used for proof-of-concept flight test. This effort also initiated investigations into a differential space-time coding technique that is compatible with existing modulation waveforms.

The SHF Channel Modeling and Implementation project completed an analytical study on the multipath effects in SHF bands. This project also initiated experimentation efforts for flight test to verify analytical results. The SHF Propagation Study identified a series of attenuation issues within the SHF bands and identified potential SHF bands where telemetry communications are possible. These results will support the T&E community during the 2007 World Radio Conference.

The Radio Frequency (RF) Microelectromechanical Systems (MEMS) Antenna project successfully demonstrated, through analysis and simulation, an RF MEMS antenna concept in preparation for antenna hardware fabrication. This technology will support a software-defined antenna that could be applied to steerable gain antennas to increase telemetry link performance margins. The Phased Array Antenna project is developing adaptive coherent combining feed technology and neural network algorithms to provide improved accuracy pointing for the ground antennas used for telemetry systems. In FY 2003, this effort developed a preliminary version of adaptive algorithms that do not require knowledge of the antenna pointing direction and can allow an antenna to be used for reception of multiple telemetry signals.

FY 2004 Plans:

The Spectrum Efficient Technology focus area will mature prior years' efforts and identify new efforts to begin in FY 2005. Flight demonstrations will be initiated to conduct prototype demonstration and model validation based on prior year project results. Additional efforts into optical communications and other communication standards will be initiated. Specific plans for Spectrum Efficiency focus area projects are:

- Spectrally Efficient High Data Rate Telemetry System for SHF will continue to address unique T&E environmental conditions such as multi-path and high test vehicle speeds. The AOFDM prototype fabrication with high mobility synchronization will be completed and demonstrated in flight test.
- Steerable Beam, Directional Antenna Concepts will complete design and development of a prototype steerable beam antenna system and perform ground tests to characterize performance in preparation for flight test.
- RF MEMS Antenna will determine parasitic interactions between pixel elements used to form antennas and design a feed/antenna configuration for optimal performance using RF MEMS. The Phase II effort to build an integrated RF MEMS antenna brassboard demonstrator will be initiated.
- Phased Array Antenna will continue to develop autonomous neural network and low complexity antenna pointing algorithms that improve the pointing accuracy and pointing speed of ground antennas utilized for test and evaluation. This effort will develop diversity combining algorithms that work on multiple receiving elements to provide significant signal to noise ratio gains in fast and frequency selective fading environments via real-time adaptive algorithms.
- Spectrum Efficient Range Communications will determine applicability of specific technologies to achieve spectrally efficient test and training range communications

FY 2005 and Future Plans:

Additional investigations will be initiated as a result of the Program Research & Development Announcement process to address critical T&E technology issues such as:

- Deconfliction of RF spectrum usage for T&E in Joint Urban Operations (JUO)
- Smart (adaptive) antenna arrays for unobtrusive and non-interfering operations for system-under-test, and variable beamwidth directional antennas for frequency sharing
- Techniques for overcoming transmission losses during ionization periods of hypersonic systems testing
- More efficient and reliable portions of the RF spectrum for future telemetry, command and control, and datalink communications for T&E and training
- Ultra-high data rate pre-processing, compression, storage, and bandwidth- efficient modulation schemes for transmission
- Remotely tunable datalink transceivers for security, safety, and inter-range operations
- Doppler shift compensation for coherent receivers

C. (U) OTHER PROGRAM FUNDING NA

RDT&E PROJECT JUSTIFICATION SHEET (R-2a)	February 2004
OPERATIONAL TEST AND EVALUATION, DEFENSE (0460) BUDGET ACTIVITY THREE, PE 0603941D	MULTI-SPECTRAL TEST

$'s in Millions	FY 2003	FY 2004	FY 2005	FY 2006	FY 2007	FY 2008	FY 2009
Multi-Spectral Test	1.498	2.079	2.620	3.171	5.190	8.248	12.728

A. (U) MISSION DESCRIPTION AND BUDGET ITEM JUSTIFICATION

DoD S&T programs are developing new technologies for use in multi- and hyper-spectral sensors, seekers, detectors, and target designators for weapon systems and battle damage assessments. T&E of new multi- and hyper-spectral sensors to be used in these future weapon systems will require new T&E technologies. T&E investment programs, such as the Central Test and Evaluation Investment Program (CTEIP) and Service improvement and modernization programs, are addressing some basic multi-spectral requirements using off-the-shelf technologies. However, T&E of future multi- and hyper-spectral systems will require technologies and procedures not yet developed or available for T&E purposes. Without these new T&E technologies, DoD will not be able to adequately test and evaluate the multi- and hyper-spectral weapon systems of the future.

B. (U) ACCOMPLISHMENTS/PLANNED PROGRAM

	FY 2003	FY 2004	FY 2005
Multi-Spectral Test	1.498	2.079	2.620

FY 2003 Accomplishments:

The Multi-Spectral Test focus area advanced the efforts that were initiated in FY 2002 through proof-of-concept and breadboard demonstrations. One new effort was initiated.

Development of the Dynamic Hyper-spectral Thermal Signature Model continued. This model will provide a method to generate high fidelity vehicle and background hyper-spectral scenes to include interactions between vehicle and terrain, vegetation, and cultural objects (plume, dust, smoke, tracks, shadows, etc.). This project successfully accomplished a proof-of-concept demonstration that generated a hyper-spectral scene from synthetically generated data.

The Phase I investigation and proof-of-concept demonstration of the adaptive Multi-spectral Stimulator Injection Test Method was successfully completed. This effort demonstrated the ability to use a common scene with a radio frequency (RF) and infrared (IR) stimulator to create a simultaneous multi-spectral scene for injection into hardware and software under test.

The Hyper-spectral Testbed Design project demonstrated the ability to integrate a hyper-spectral scene generator and sensor. The proof-of-concept testbed integrated a thermal pixel array with a reverse spectrometer and successfully injected a scene into a sensor.

The Hyper-spectral Sensor Evaluation – Minimum Resolvable Temperature (MRT) effort was initiated to determine methods for analyzing the performance of under-sampled imagers (e.g. new Focal Plane Arrays (FPAs)) to replace the current MRT test procedures, which were adequate for sensors in the past, but are inadequate for T&E of FPAs.

FY 2004 Plans:

The T&E/S&T program Multi-Spectral Test focus area will mature prior years' efforts and identify new efforts to begin in FY 2005. Specific plans for the multi-spectral test projects are:

- Dynamic Hyper-spectral Thermal Signature Model will continue the development of an open-source high-fidelity multi- and hyper-spectral vehicle/background signature model (visible through IR). Effort will continue to add operational level detail to the signature model: additional vehicle models, two-way background interactions, 3-dimensional terrain, vegetation, and cultural objects.
- Multi-spectral Stimulator Injection Test Method will continue development of a multi-spectral stimulator to provide T&E support for multi-mode seekers in the laboratory and field environments. This year's plans include demonstration of closed-loop stimulation for T&E of trackers, automatic target recognition systems, terrain and clutter analysis, and evaluation of sensor fusion.
- Hyper-spectral Testbed Design will continue development of the Long Wave Infrared (LWIR) Hyper-spectral Scene Projector by demonstrating the integration of the LWIR Acoustic Optical Thermal Filter into the current test bed, and validating testbed operation with additional sensors. A Phase II prototype Hyper-spectral Scene Projector with the desired temperature range capability will be designed.
- Hyper-spectral Sensor Evaluation – Minimum Resolvable Temperature will continue research of potential methods for measuring the performance of focal plane arrays (lab tests, field performance validation, theoretical models). FY 2004 efforts include experimentation with lab measurements and sensor parameters combined for an accurate field-relatable metric to determine performance of focal plane arrays.

FY 2005 and Future Plans:

Complete all four of the ongoing FY 2004 efforts and to initiate new investigations into visible and near-IR multi-spectral and hyper-spectral sensor testbeds, real time hyper-spectral data processing and analysis, and Bi-directional Reflectance Distribution Function. Additional investigations will be initiated to address other multi-spectral and hyper-spectral sensor test technology issues such as:

- Hyper-spectral visible/near-IR scene generation model integration
- Common usage, tunable, full spectrum, and high-resolution scene generators

- Common usage, threat representative, full spectrum, and high-resolution dynamic targets
- Countermeasure environments, countermeasure applications, and closed loop counter-countermeasure capabilities
- Improved models for all-weather scenario drivers and target presentations
- Ladar, and other multi-spectral test generator and standoff sensors
- Joint Urban Operations scenarios
- Sensor-to-shooter system and sensor-to-fusion-to-shooter system performance
- Far-field signal simulations in near-field
- Unobtrusive sensor integration and fusion monitoring
- Hardware-in-the-loop and installed-system test facility capabilities
- Human-in-the-loop and associated Human Systems Interface (HSI) issues
- Focal plane array (FPA) technologies, frequency-hopping sensors, multi-spectral/hyper-spectral imaging, active illumination, passive polarization, passive millimeter wave, foliage penetration, synthetic-aperture radar, and electronic stabilization
- Fusion of multiple advanced sensor components, the application of the aided target recognition algorithms to these advanced sensors
- Positive identification of non-cooperative air targets, over-the-horizon targeting, and battle damage assessment
- Tools to evaluate hyper-spectral-polarimetric sensors
- Tools and techniques to evaluate active multi-spectral sensor systems
- T&E of signal processing hyper-spectral algorithm effectiveness
- Sensor-to-shooter system interface analysis (human-in-the-loop testing)
- Hyper-spectral analysis tool for handling and collating T&E data
- Methodologies for evaluating sensor-to-sensor transition (e.g. acoustic/IR, Millimeter Wave (MMW)/IR systems)

C. (U) <u>OTHER PROGRAM FUNDING</u> NA

RDT&E PROJECT JUSTIFICATION SHEET (R-2a)	February 2004
OPERATIONAL TEST AND EVALUATION, DEFENSE (0460) BUDGET ACTIVITY THREE, PE 0603941D	EMBEDDED INSTRUMENTATION

$'s in Millions	FY 2003	FY 2004	FY 2005	FY 2006	FY 2007	FY 2008	FY 2009
Embedded Instrumentation	1.417	3.309	2.663	3.982	4.983	7.949	11.743

A. (U) MISSION DESCRIPTION AND BUDGET ITEM JUSTIFICATION

Instrumentation requirements for systems-under-test, hardware-in-the-loop testing, and training are increasing exponentially for new weapons; command, control, communications, and computers, intelligence, surveillance, and reconnaissance (C4ISR), and target systems. Onboard or personnel-borne instrumentation and equipment is required for sensing and collecting critical performance data; data storage and transmission; determining accurate time, space, position, and attitude information; interfacing with command and control data links; monitoring and reporting system-wide communications; and reporting human operator performance. These requirements drive the need for enabling technologies for miniaturized non-intrusive instrumentation suites that demonstrate increased survivability. These lightweight instrumentation suites need to have improved sensitivity sensors, increased embedded data processing capacity, and both plug-and-play and open architectures to support multiple applications and users (development, test and evaluation, training, logistics (intelligent diagnostics/prognostics) and employment effects).

There is minimal space available for adding instrumentation to new weapon systems subsequent to their development. Additional weight and power draw can adversely affect the weapon system performance. Providing space and power in small weapons, such as miniature-unmanned vehicles and robotics, and targets remains a challenge. Instrumentation for humans-in-the-loop, such as a dismounted soldier in an urban environment, should not detrimentally affect the soldier's performance or impact his operational burden. New technologies can be exploited to integrate small non-intrusive embedded instrumentation (EI) into new platforms during design and development, and, in some cases, for incorporation into existing platforms. This embedded instrumentation can provide the required data for T&E training, maintenance, and logistics support throughout the system lifecycle and will enhance the ability to document system performance during combat missions. As recognized by Business Initiative Council (BIC) Initiative TE-08, embedded instrumentation for T&E, training, maintenance, and logistics will significantly reduce the development, acquisition, and total ownership costs of new weapon and C4ISR systems while enhancing force readiness. Accordingly, acquisition programs are to integrate EI into platform designs up front, if reasonable and practical, as a key enabling tool for transformation.

(U) B. ACCOMPLISHMENTS/PLANNED PROGRAM

	FY 2003	FY 2004	FY 2005
Embedded Instrumentation	1.417	3.309	2.663

FY 2003 Accomplishments:

The Embedded Instrumentation focus area sponsored several projects in FY 2003 to investigate technologies needed by the T&E community.

The Direct Methanol Fuel Cell (DMFC) project is developing an advanced power supply to support operational testing of ground-based weapon systems, such as Future Combat Systems. Key components of the fuel cell assembly were manufactured in preparation for a prototype demonstration.

The Carbon Monoxide (CO) Emissions Sensor for Gas Turbine Engines project initiated the development of MicroElectroMechanical Systems (MEMS) based sensors to support the T&E of combustion engines. This sensor will be embedded near the harsh combustor region of air-breathing engines, such as those used for hypersonic aircraft, to directly measure carbon monoxide emissions. This data is a key indicator of engine performance.

The Compact Holographic Data Storage project is developing a compact, high-speed, high density (>500 GB) embedded data storage device that has no moving parts. The holographic data storage effort demonstrated the ability to read and write data to a crystal and completed development of a breadboard design.

The Advanced Munitions Flight Test Instrumentation project is developing MEMS based sensors to couple with a munitions telemetry device to allow acquisition and transmission of critical test data during munitions testing. This effort performed a series of shock tests to qualify MEMS devices under munitions shock loads for potential incorporation into the prototype instrumentation package.

The EI Working Group used the Broad Agency Announcement process to select efforts for FY 2004 investigation.

FY 2004 Plans:

The Direct Methanol Fuel Cell project will be completed during FY 2004 with a field demonstration of the system at Fort Hood, TX. The remaining efforts described above will continue through FY 2004. Specific plans are:

- The CO Emissions Sensor will fabricate a MEMS CO system and begin a series of demonstrations and tests.
- The Compact Holographic Data Storage will begin the Phase II development of an integrated optics, laser source, and input/output controller in a stand-alone brassboard demonstration system. The Advanced Munitions Flight Test Instrumentation project will integrate a single chip, 3-axis accelerometer into a packaged configuration, and design and fabricate a 2-axis Vibrating Bar Magnetometer for incorporation into a prototype module.
- The following efforts will initiate in FY 2004:
  - The Gas Turbine Engine Embedded Probe project will design and fabricate a gas extraction probe capable of being embedded

within a combustor for use with emissions sensors. The FY 2004 efforts include design and fabrication of a proof-of-concept probe.

- The Wideband Energy Harvesting for Embedded Sensors effort will design, fabricate, and demonstrate a prototype piezoelectric energy harvester to provide power to stand-alone MEMS sensors.
- The D-fiber for Multidimensional Sensor Application will use D-fiber to develop multi-axis stress and temperature sensors. The FY 2004 effort will fabricate suitable gratings on D-fiber, embed fibers on a proof-of-concept test article, and demonstrate multi-axis stress and temperature sensing.
- The Micro-machined Pressure, Temperature, and Shear Stress Sensors project will embed MEMS sensors directly in optical fiber. The FY 2004 efforts will design and fabricate individual pressure, temperature, and shear stress sensors, and embed them on a test article for demonstration.
- Additional planned efforts for FY 2004 include investigation of a Soldier EI system and an embeddable MEMS-based emissions gas analyzer.

FY 2005 and Future Plans:

The FY 2003 projects will complete in FY 2005/2006 with prototype demonstrations. Efforts will advance on the projects initiated in FY 2004 as well. The EI Working Group will examine EI test technology issues to determine the highest priorities for funding future projects. Some projects may begin in FY 2005; however, the EI Working Group will issue a Broad Agency Announcement to select the larger efforts for FY 2006 investigation. These efforts will focus on additional EI test technology issues such as:

- Miniaturization and reduced-weight instrumentation packaging
- Improved sensor techniques
- Higher bandwidth data encryption
- Human performance instrumentation (e.g., Joint Urban Operations T&E)
- Non-intrusive interfaces with critical operational components including the MIL-STD-1553 data bus
- Conformal and non-interfering antennas
- Survivability in harsh environments, such as hypersonic speeds or electronic warfare
- Wireless data and communications transfers and distribution
- Plug and play architecture for common usage
- Reductions in on-board power demands
- Instrumentation command and control
- Data fusion
- Vehicle power lines as a data bus
- Conformal externally mounted instrumentation
- Electro-adhesives

- Small RF transceivers
- Ultra tightly coupled, integrated M-code Global Positioning System/Inertial Measurement Unit modules for high dynamic vehicles
- High anti-jam signal processing techniques for operations in an electronic warfare and jamming environment
- Smaller, higher capacity recorders to support passive operation
- More powerful micro-processors to support advanced simulations
- Compact and stable timing reference units
- Passive devices for improving ground truth measurements, such as for attitude and miss-distance measurements.

C. (U) OTHER PROGRAM FUNDING NA

RDT&E PROJECT JUSTIFICATION SHEET (R-2a)	February 2004
OPERATIONAL TEST AND EVALUATION, DEFENSE (0460) BUDGET ACTIVITY THREE, PE 0603941D	DIRECTED ENERGY TEST

$'s in Millions	FY 2003	FY 2004	FY 2005	FY 2006	FY 2007	FY 2008	FY 2009
Directed Energy Test	1.152	3.006	4.327	5.887	9.763	14.967	24.808

A. (U) MISSION DESCRIPTION AND BUDGET ITEM JUSTIFICATION

Directed energy (DE) technologies are rapidly transitioning into acquisition programs and Advanced Concept Technology Demonstrations (ACTDs). These weapons technologies, which primarily consist of High Energy Laser (HEL) and High Power Microwaves (HPM), are outpacing their supporting test technologies. Advancements in HEL and HPM have created a new class of weapon systems in which energy is placed on a target instantaneously, making traditional test techniques for evaluating conventional munitions (with flight times ranging from seconds to minutes, and that depend on various forms of physical contact for kill) not applicable to DE systems' T&E. As a result, adequate developmental, live fire, and operational test technology may not be available when the DE acquisition programs are ready to test.

Current DE developments include: HPM command and control warfare/information warfare, Active Denial Systems, Advanced Tactical Laser, Air Force Airborne Laser, Army Tactical High Energy Laser, Army Mobile Tactical High Energy Laser, Navy Free Electron Laser, Solid State Laser, and Space Based Laser. These DE systems will precipitate a revolutionary change on future engagements, employments, concepts of operations, and T&E. Lasers can be precisely focused on a target to provide surgical strike capability at very long ranges. Once on target, lasers affect the target from the outside by rapid heating, causing localized burn-through to create structural degradation or destruction and observable attributes of a hard kill. Conversely, high-power microwaves flood target areas with energy—allowing for the engagement of multiple targets at the same time. High power microwaves affect the target from the inside through electrical system disruption and burn-out for a soft kill. These differences notwithstanding, both HEL and HPM have some very important common traits. Both types of directed energy travel to the target at the speed of light, are capable of graduated effects (deny, disrupt, degrade, and/or destroy), and can be used to minimize collateral damage. These revolutionary operational capabilities will require revolutionary T&E scenarios, technologies, and analysis tools that do not exist today.

Current DE system and component testing usually includes two principal thrusts: how well is the weapon performing, and what is the specific interaction of energy and target. Military utility of these weapons will be dependent on the knowledge acquired through T&E to know how much

to trust the technologies under development and how best to use them. Consequences of not providing adequate T&E capabilities for the new DE technologies and systems include:

- Not knowing if the system can be safely deployed
- Not knowing if the system achieves the proper target kill rate
- Risk of apparent poor system performance during T&E leading to unjustified program cancellation
- Risk of fielding an ineffective system due to inadequate T&E
- Delays in meeting critical Transformation Objectives

B. (U) ACCOMPLISHMENTS/PLANNED PROGRAM

	FY 2003	FY 2004	FY 2005
Directed Energy Test	1.152	3.006	4.327

FY 2003 Accomplishments:

Three efforts were initiated in the DE Test focus area in FY 2003.

The first effort was the development of a Beam Redistribution System (BRS) to allow far-field laser effects to be created in a near-field environment using a portable optical system. This will allow characterization of the beam without requiring the long ranges necessary to achieve these effects. In FY 2003, two parallel approaches to develop conceptual designs were completed. One approach was downselected for Phase II award, which will begin in FY 2004.

The second effort was to develop a Four-Color Quantum Well Infrared Photodetector (QWIP). The QWIP will allow for remote sensing and characterization of a multiple laser wavelength system as it interacts with a target. In FY 2003, the QWIP project advanced the system design, completing efforts for Near IR reflective optics and computer generated diffractive optical grating.

The final effort initiated in FY 2003 was the Directed Energy Data Acquisition Transformation (DEDAT) project. DEDAT is developing instrumentation solutions to allow for T&E of HPM systems. In FY 2003, DEDAT initiated design studies for E-field probes, digitizers, and electromagnetically-hardened instrumentation.

FY 2004 Plans:

The three existing DE Test projects will continue development through FY 2004. The BRS system will complete the Phase II demonstration in FY 2004. The QWIP will complete design, and begin fabrication, integration, and test of system components. DEDAT will prototype a compact remote digitizer and electromagnetically-hardened sensor electronics. New efforts will begin in the development of a system to characterize optical turbulence along the beam path for laser system T&E; laser beam characterization through the use of instrumented target boards and on-target beam sensors; and development of survivable, autonomous HPM field diagnostics.

FY 2005 and Future Plans:

The QWIP and DEDAT will complete in FY 2005 with system prototype demonstrations. Efforts will advance on the projects initiated in FY 2004 as well. Future investigations will focus on key technologies to support collection of data both remotely and on-target for HEL and HPM testing. This includes, but is not limited to, data associated with imaging, spectral content, laser-target interaction signature, "kill" mechanisms, atmospheric refraction, scattering, absorption and propagation data, beam quality, jitter, energy fluence on target, aim point maintenance, data recording, spectrally efficient data links, high-rate image/data reduction and visualization tools, etc. Investigations will include:

- HEL and HPM power measurement on target: Examine various sensor approaches or materials that can be incorporated into airborne and ground targets to measure DE on target. Sensors/material must be able to be applied/integrated into a variety of platforms, to include airborne and ground-based, and provide for minimal interference with system operation to provide a measure of beam energy on target. Inability to collect DE on target will preclude ability to measure effectiveness of emerging DE weapon systems.
- DE-hardened flight termination system/range destruct package: Study and assess requirements for DE "hardened" flight termination systems. These systems must be able to safely and reliably provide for termination of the target, even when high concentrations of DE are present on the target. This should include both HEL and HPM. Current flight termination systems may either be negated or pre-maturely initiated by the presence of RF energy or high-fluence laser energy. Impact of flight termination system failure due to DE could include damage to unintended targets, unrecoverable targets, and threat to life and areas surrounding the test area.
- DE beam prediction/detection/display: Develop capability to accurately predict and understand where HEL and HPM energy is actually projected—this is critical to T&E and safety. Study of wide-spectrum, single substrate imagers seeks to enhance technology for imaging and detection of HEL beams from a variety of systems/sources. These enhancements would address limitations in spectral coverage of various narrow spectrum, single substrate imagers. Current technology requires multiple sensor/optic combinations to cover the spectral range of existing HELs, which is cost prohibitive. Single wide-spectrum imagers would eliminate the need for multiple, costly sensor/optics combinations.
- Modeling and simulation (M&S) to extend test results: Incorporate physics-based models into virtual graphical representations of T&E ranges to provide 3-dimensional, geodetically accurate models of beam propagation, beam spread, lethal range, fluence on target, and atmospheric effects. These models could be used to predict hazardous DE fluence and beam propagation for a given test scenario, plan and model RF or HEL fluence in a test or target area to rehearse test conduct, and provide for a robust DE 3-dimensional visualization capability for T&E ranges. Current 3-dimensional models are based on digital terrain data and can incorporate time-space position information from various sources such as radar and GPS, but lack physics-based models to predict laser or RF weapon system performance.

C. (U) OTHER PROGRAM FUNDING NA

RDT&E PROJECT JUSTIFICATION SHEET (R-2a)	February 2004
OPERATIONAL TEST AND EVALUATION, DEFENSE (0460) BUDGET ACTIVITY THREE, PE 0603941D	INFORMATION SYSTEMS TECHNOLOGY TEST

$'s in Millions	FY 2003	FY 2004	FY 2005	FY 2006	FY 2007	FY 2008	FY 2009
Information Systems Technology Test	0.000	0.050	1.100	1.968	2.247	3.447	4.077

A. (U) MISSION DESCRIPTION AND BUDGET ITEM JUSTIFICATION

The S&T community is developing advanced information systems technology (IST), both in Advanced Concept Technology Demonstrations (ACTDs) and in acquisition programs, to support DoD's Critical Transformational Capabilities—Conduct Information Operations, Deny Enemy Sanctuary, and Leverage Information Technologies. Successful implementation of these transformational capabilities will necessitate a corresponding transformation in DoD's ability to test and evaluate IST. Emerging revolutionary operational capabilities will require revolutionary OT&E scenarios, technologies, and analysis tools to ensure that new systems are adequately tested for operational use.

Advancements in communications and computing power are creating a new class of information systems. New IST will provide commanders and staffs with an adaptive, decision-centered, configurable information visualization environment, which will improve the speed and quality of command decisions. Other advances will enable a spectrum of capabilities ranging from advanced management and exploitation of intelligence, surveillance, and reconnaissance assets to next-generation tactical radio systems. Information assurance and survivability are central to IST development.

This T&E/S&T focus area will address the T&E capability required to ensure that the IST provided to the warfighter will deliver the assured and survivable ability to acquire, verify, protect and assimilate information necessary for our forces to neutralize and dominate any future adversary within a complex network-centric battlefield environment.

B. (U) ACCOMPLISHMENTS/PLANNED PROGRAM

	FY 2003	FY 2004	FY 2005
Information Systems Technology Test	0.000	0.050	1.100

FY 2003 Accomplishments:

In FY 2003, the roadmap for the IST Test focus area was developed as part of the T&E/S&T Program Test Technology Area Plan (TTAP). The IST Test focus area was reassessed for criticality and determined to merit initiation of activity in FY 2004.

FY 2004 Plans:

Although substantive efforts are planned to begin in FY 2005, the program will establish the foundation for the focus area in FY 2004. This effort includes exploration into centers of excellence for IST Test and identification of subject matter experts in this field. The T&E/S&T Program will issue a Broad Agency Announcement to select efforts for FY 2005 investigation. The focus will be developing and demonstrating technologies to objectively test IST. Areas of potential investigations are:

- Development of non-intrusive instrumentation and T&E communication networks (including networks of networks) that do not affect the performance of information systems under evaluation, especially for humans-in-the-loop network-centric environments
- Techniques for capturing spatial and temporal registration across large numbers of sensors, multimedia communications, and human-system interface devices
- Ability to assess information assurance within complex systems of systems
- Techniques to assess low probability of detection/low probability of intercept communications
- Techniques for capturing and evaluating multiple simultaneous collaborative user communications
- Ability to evaluate the success of information operations in terms of mission accomplishment, survivability of friendly forces, neutralization of enemy capabilities, etc.
- Techniques for capturing and evaluating human physical and cognitive performance
- Developing T&E capability to evaluate IST advances from a "human-out" perspective; i.e., determine what information actually enhances a warfighter's performance
- Methods for verification, validation, and accreditation of IST modeling and simulation

FY 2005 and Future Plans:

Efforts selected during FY 2004 will be initiated in FY 2005. Other IST T&E technology issues identified in FY 2004 and FY 2005 will be addressed in future plans. These efforts will focus on T&E capabilities required to assess the contribution of IST to decision superiority in operational scenarios. Advanced information systems must be assessed as "force multipliers" in network-centric operations. An objective methodology is required to assess operational effectiveness of warfighters while employing information systems of systems, especially the effect of information systems on human cognitive decision processes. Additional investigations will be initiated to address the technology issues associated with these and other facets of IST test.

C. (U) OTHER PROGRAM FUNDING NA